DESTRUCTIVE TESTS

As the name suggests, destructive testing (DT) includes methods where the material is broken down in order to determine mechanical properties, such as strength, toughness and hardness.

Advantages of Destructive Testing (DT)

- Verifies properties of a material
- Determines quality of welds
- Helps to reduce failures, accidents and costs
- Ensures compliance with regulations

TENSILE TEST

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test is performed on a material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension. As the material is being pulled, you will find its strength along with how much it will elongate.

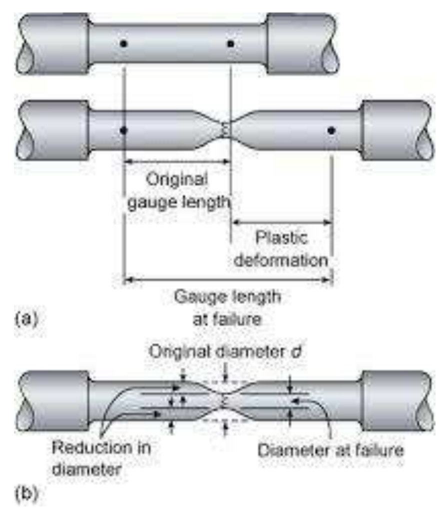

Fig: 1

COMPRESSION TEST

Method for determining behavior of materials under crushing loads. Specimen is compressed, and deformation at various loads is recorded. Compressive stress and strain are calculated and plotted as a stress-strain diagram which is used to determine elastic limit, proportional limit, yield point, yield strength and (for some materials) compressive strength. Standard compression tests are given in ASTM C-773 (high strength ceramics), ASTM E-9 (metals), ASTM E-209 (metals at elevated temperatures) and ASTM D-695 (plastics).

The ASM Handbook®, Volume 8, Mechanical Testing and Evaluation states: "Axial compression testing is a useful procedure for measuring the plastic flow behavior and ductile fracture limits of a material. Measuring the plastic flow behavior requires frictionless (homogenous compression) test conditions, while measuring ductile fracture limits takes advantage of the barrel formation and controlled stress and strain conditions at the equator of the barreled surface when compression is carried out with friction. Axial compression testing is also useful for measurement of elastic and compressive fracture properties of brittle materials or low-ductility materials. In any case, the use of specimens having large L/D ratios should be avoided to prevent buckling and shearing modes of deformation[1]."

The image at right shows variation of the strains during a compression test without friction (homogenous compression) and with progressively higher levels of friction and decreasing aspect ratio L/D (shown as H/D)[1].

Modes of Deformation in Compression Testing:

The figure to the right illustrates the modes of deformation in compression testing. (a) Buckling, when L/D > 5. (b) Shearing, when L/D > 2.5. (c) Double barreling, when L/D > 2.0 and friction is present at the contact surfaces. (d) Barreling, when L/D < 2.0 and friction is present at the contact surfaces. (e) Homogenous compression, when L/D < 2.0 and no friction are present at the contact surfaces. (f) Compressive instability due to work-softening material.

Typical Materials:

The following materials are typically subjected to a compression test.

- Concrete
- Metals
- Plastics
- Ceramics
- Composites
- Corrugated Cardboard

Fig: 2

BENDING TEST

The flexure test method measures behavior of materials subjected to simple beam loading. It is also called a transverse beam test with some materials. Maximum fiber stress and maximum strain are calculated for increments of load. Results are plotted in a stress-strain diagram. Flexural strength is defined as the maximum stress in the outermost fiber. This is calculated at the surface of the specimen on the convex or tension side. Flexural modulus is calculated from the slope of the stress vs. deflection curve. If the curve has no linear region, a secant line is fitted to the curve to determine slope.

A flexure test produces tensile stress in the convex side of the specimen and compression stress in the concave side. This creates an area of shear stress along the midline. To ensure the primary failure comes from tensile or compression stress the shear stress must be minimized. This is done by controlling the span to depth ratio; the length of the outer span divided by the height (depth) of the specimen. For most materials S/d=16 is acceptable. Some materials require S/d=32 to 64 to keep the shear stress low enough.

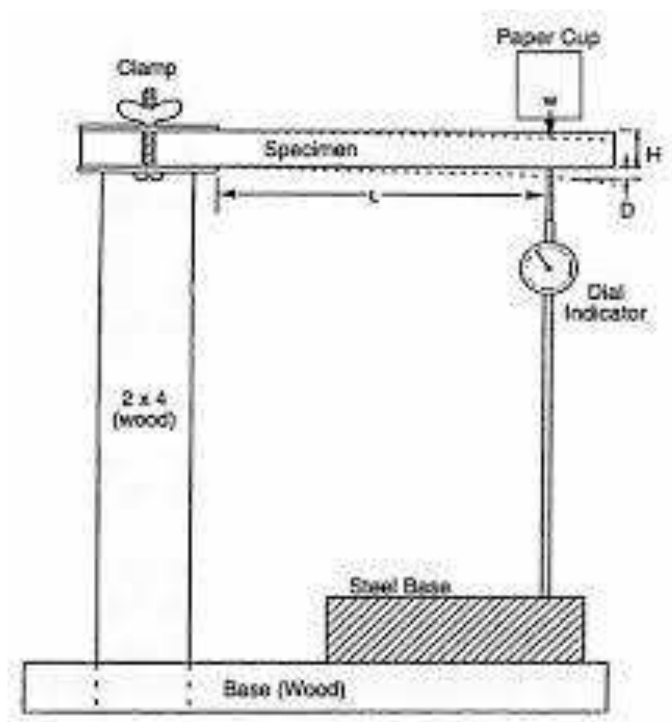

Fig: 3

TORSION TEST

A torsion test measures the strength of any material against maximum twisting forces. It is an extremely common test used in material mechanics to measure how much of a twist a certain material can withstand before cracking or breaking. This applied pressure is referred to as torque. Materials typically used in the manufacturing industry, such as metal fasteners and beams, are often subject to torsion testing to determine their strength under duress.

There are three broad categories under which a torsion test can take place:

- **Failure testing:** it involves twisting the material until it breaks.
- **Proof testing:** it is used to observe whether a material can bear a certain amount of torque load over a given period of time.
- **Operational testing:** it is used to test specific products to confirm their elastic limit before going on the market.

It is critical for the results of each torsion test to be recorded. Recording is done through creating a stress-strain diagram with the angle of twist values on the X-axis and the torque values on the Y-axis. Using a torsion testing apparatus, twisting is performed at quarter-degree increments with the torque that it can withstand recorded. The strain corresponds to the twist angle, and the stress corresponds to the torque measured.

After testing, metal materials are categorized as being either ductile or brittle. Ductile metals such as steel or aluminum have high elastic limits and can withstand a great deal of strain before breaking. Brittle materials such as cast iron and concrete have low elastic limits and do not require much strain before rupturing.

Without performing a torsion test, materials would not be properly vetted before being released for industrial use. It is of paramount importance that the ability for a material to bear a certain amount of twisting is accurately measured. Otherwise, structures and machines that depend on such materials could break down causing instability, work flow interruption or even significant damage and injury.

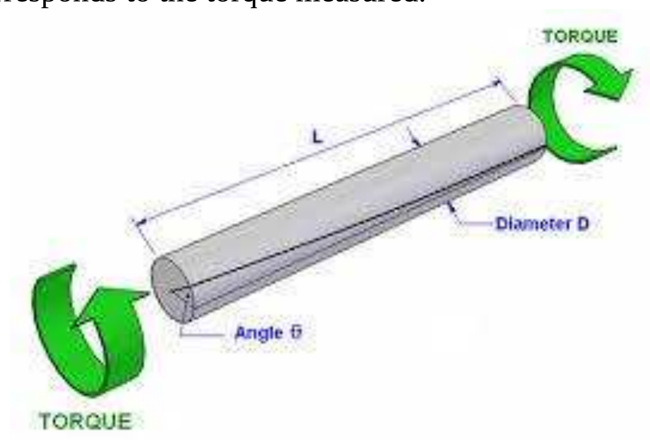

Fig: 4

- Torsion test is not widely accepted as much as tensile test.
- Torsion tests are made on materials to determine such properties as the modulus of elasticity in shear, the torsion yield strength and the modulus of rupture.
- Often used for testing brittle materials and can be tested in full-sized parts, i.e., shafts, axles and twist drills which are subjected to torsional loading in service.

HARDNESS TEST:

Hardness is the resistance of a material to permanent indentation. It is important to recognize that **hardness test is an empirical test** and therefore hardness is **not a material property**. This is because there are several different hardness tests that will each determine a different hardness value for the same piece of material. Therefore, hardness depends on the test method and every test result has a label identifying the test method used.

Hardness is, however, used extensively to characterize materials and to determine if they are suitable for their intended use or not. All of the hardness tests described below involves the use of a specifically shaped indenter, significantly harder than the test sample that is pressed into the surface of the sample using a specific force. Either the depth or size of the indent is measured to determine a hardness value.

Advantages of Hardness Test:

- Easy to perform
- Quick - 1 to 30 seconds
- Relatively inexpensive
- Finished parts can be tested - but not ruined
- Virtually any size and shape can be tested

The most common uses for hardness tests is to verify the heat treatment of a part and to determine if a material has the properties necessary for its intended use. Establishing a correlation between the hardness result and the desired material property allows this, making hardness tests very useful in industrial and R&D applications.

Hardness Scales:

There are five major hardness scales:

- Brinell - HB
- Knoop - HK
- Rockwell - HR
- Shore - HS
- Vickers – HV

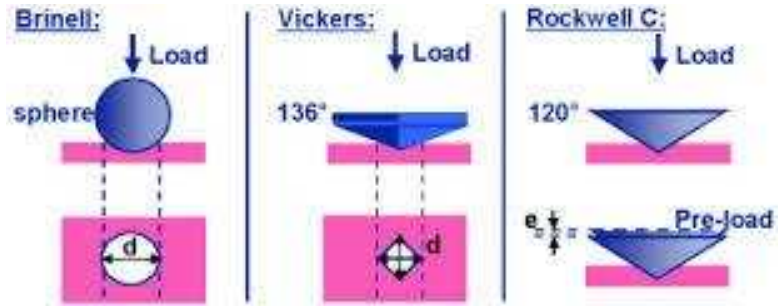

Fig: 5

Each of these scales involves the use of a specifically shaped diamond, carbide or hardened steel indenter pressed into the material with a known force using a defined test procedure. The hardness values are determined by measuring either the depth of indenter penetration or the size of the resultant indent. All of the scales are arranged so that the hardness values determined increase as the material gets harder. The hardness values are reported using the proper symbol, HR, HV, HK, etc. indicating the test scale performed.

The following five factors can be used to determine the correct hardness test for your application.

- **Material** - grain size, metal, rubber, etc.
- **Approximate Hardness** - hardened steel, rubber, etc.
- **Shape** - thickness, size, etc.
- **Heat Treatment** – through or casehardened, annealed, etc.
- **Production Requirements** - sample or 100%

HYDROSTATIC TEST

It is a test used to check leakage of weld joints, to determine axial and tangential strains of thick and thin cylinders by using strain gauges and strain meters. A hydrostatic test is a way in which pressure vessels such as pipelines, plumbing, gas cylinders, boilers and fuel tanks can be tested for strength and leaks. The test involves filling the vessel or pipe system with a liquid, usually water, which may be dyed to aid in visual leak detection, and pressurization of the vessel to the specified test pressure. Pressure tightness can be tested by shutting off the supply valve and observing whether there is a pressure loss. The location of a leak can be visually identified more easily if the water contains a colorant. Strength is usually tested by measuring permanent deformation of the container. Hydrostatic testing is the most common method employed for testing pipes and pressure vessels.

Fig: 6

Using this test helps maintain safety standards and durability of a vessel over time. Newly manufactured pieces are initially qualified using the hydrostatic test. They are then re-qualified at regular intervals using the *proof pressure test* which is also called the *modified hydrostatic test*. Testing of pressure vessels for transport and storage of gases is very important because such containers can explode if they fail under pressure.

CHARPY IMPACT TEST

The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A disadvantage is that some results are only comparative.

The test was developed around 1900 by S. B. Russell (1898, American) and G. Charpy (1901, French). The test became known as the Charpy test in the early 1900s due to the technical contributions and standardization efforts by Georges Charpy. The test was crucial in understanding the fracture problems of ships during World War II.

Today it is utilized in many industries for testing materials, for example the construction of pressure vessels and bridges to determine how storms will affect the materials used.

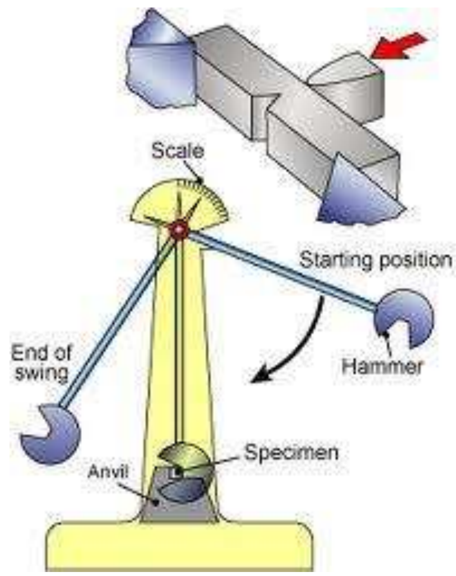

Fig: 7

NON-DESTRUCTIVE TESTS

Non-destructive testing is used as part of a manufacturing or installation inspection to check if quality demands are being met. As an example, welded steel joints are x-rayed to check the quality of the welding. The radiographic test reveals if the joint is fully welded or contains unacceptable faults.

Benefits of using NDT

- High quality
- Verifies requirements
- Prevents failure or break down of critical equipment

POLARISCOPE TEST

It is a nondestructive test used to determine stress concentration in transparent materials by studying fringe pattern.

The method is based on the property of birefringence exhibited by certain transparent materials. Birefringence is a property where a ray of light passing through a birefringent material experiences two refractive indices. The property of birefringence (or double refraction) is observed in many optical crystals. Upon the application of stresses, photo elastic materials exhibit the property of birefringence, and the magnitude of the refractive indices at each point in the material is directly related to the state of stresses at that point. Information such as

maximum shear stress and its orientation are available by analyzing the birefringence with an instrument called polariscope.

When a ray of light passes through a photo elastic material, its electromagnetic wave components gets resolved along the two principal stress directions and each of these components experiences different refractive indices due to the birefringence. The difference in the refractive indices leads to a relative phase retardation between the two components

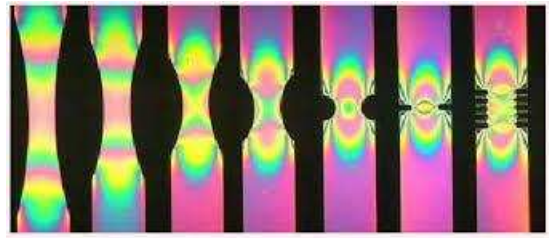

Fig: 8

RADIOGRAPHY (X-RAY TEST)

X Rays can be used for detection of internal flaws and faults in most engineering materials. X ray testing is expensive due to the costly equipment, film and processing required. There is also the need for the implementation of specialized safety equipment and procedures.

X ray or Gamma radiation is passed through the test specimen and then recorded upon a photo-sensitive film. The flaws or defects are indicated as dark areas on the film because faults absorb less radiation than the material itself. Complex shapes require examination from two different angles.

- Due to its expense X ray detection is generally used during product development, or in laboratory testing.
- Gamma radiation is suited to field or on site applications as less complex equipment is used.

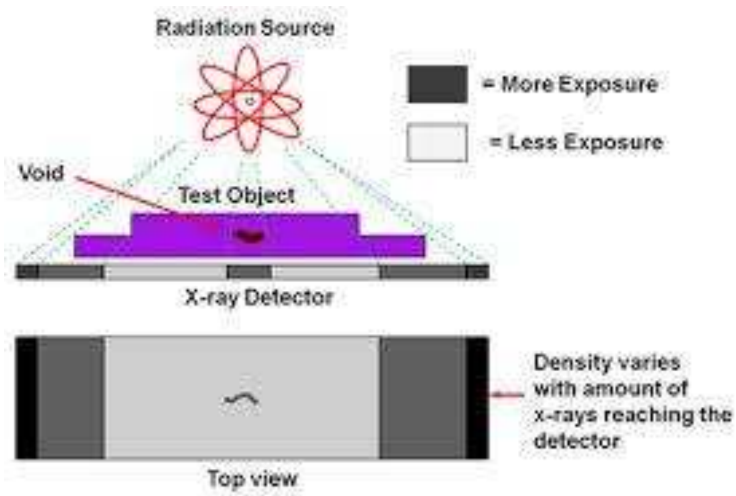

Fig: 9

MAGNETIC PARTICLE INSPECTION TEST

Magnetic particle tests are suitable only for ferrous metals capable of being magnetized. Almost any size or shaped component can be tested. The test specimen is first thoroughly cleaned and dried before the test. When magnetized ferromagnetic specimens have a distorted magnetic field in the region of the fault or defect.

This distortion can be seen with the application of magnetic particles as a powder or suspended in a liquid. These particles are often coated in a fluorescent material enabling inspection under ultraviolet light. The flaw can be seen as a disturbance in the flow lines. Faults perpendicular to induced field are easily detected, whereas faults parallel to the induced field may be misinterpreted. To avoid this, inspections and magnetization, should be carried out from different orientations. If a permanent record is required a photograph, videotape or inspectors report may be kept.

Specialized techniques of recording the defect patterns are also available.

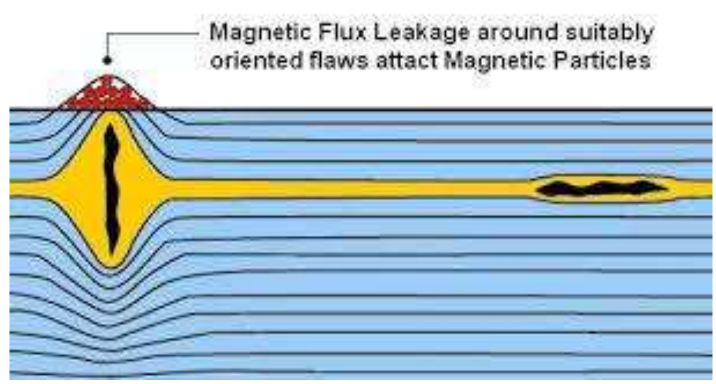

Fig: 10

DYE PENETRANT TEST

The test specimen is first thoroughly cleaned and dried before the test. A liquid penetrant is applied to the surface; spraying, dipping or brushing may do this. Over a period of time the liquid penetrant is drawn into any surface faults by capillary action, any excess liquid is removed. Depending on the process being used, the surface is coated with whiting or a developer. Faults open to the surface will appear as a discoloured line in the whiting. Fluorescent or coloured dyes drawn into the faults are readily seen under ultraviolet light or as a line in the developer. Liquid penetrant tests are simple, versatile, portable and inexpensive. The results are easy to interpret but only surface faults can be detected. If a permanent record is required a photograph or videotape or inspectors report may be kept. The use of laser scanners and digital control allows this process to be used as a mass production technique.

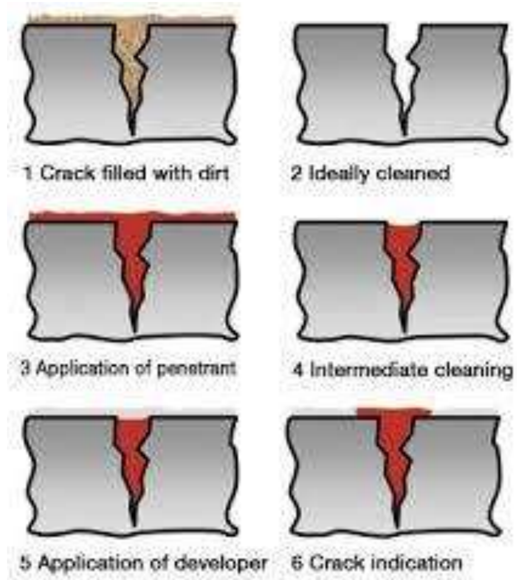

Fig: 11

FLUORESCENT TEST

FLUORESCENT PENETRANT INSPECTION (**FPI**) is a nondestructive testing method for detecting discontinuities (cracks, seams, laps, cold shuts, laminations, and porosity) that are open to the surface. It is a type of dye penetrant inspection in which a fluorescent dye is applied to the surface of a non-porous material in order to detect defects that may compromise the integrity or quality of the part in question. Noted for its low cost and simple process, FPI is used widely in a variety of industries.

Inspection Steps:

The following are the main steps in a Fluorescent Penetrant Inspection Process:

1. Initial Cleaning:
2. Penetrant Application:
3. Excess Penetrant Removal:
4. Developer Application:
5. Inspection:
6. Final Cleaning

Fig: 12

Advantages:

- Highly sensitive fluorescent penetrant is ideal for even the smallest imperfections
- Low cost and potentially high volume
- Suitable for inspection of non-magnetic materials and electrical insulators.

Potential Disadvantages:

- The method requires thorough cleaning of the inspected items. Inadequate cleaning may prevent detection of discontinuities.
- Test materials can be damaged if compatibility is not ensured. The operator or his/her supervisor should verify compatibility on the tested material, especially when considering the testing of plastic components and ceramics. The method is unsuitable for testing porous ceramics.
- Penetrant stains clothes and skin and must be treated with care
- The method is limited to surface defects.
- Training is required for the inspector.

Ultrasonic testing offers immediate results and a high degree of accuracy for cracks and internal faults such as gas porosity. The test is suitable for metals, plastics, glass, concrete and ceramics. Components that are thin, small, have complex shapes or have rough surfaces are difficult to test. Ultrasonic testing involves sending high frequency vibrations (100 kHz to 200 kHz) through a material and sensing their reflections. The high frequency vibrations are produced by a transducer, which uses a piezoelectric crystal to convert electrical oscillations into mechanical vibrations. The transducer is placed on the surface of the material to be tested. Vibrations penetrate the material and are refracted and reflected at discontinuities within the material. Another transducer picks up the reflected signal which is displayed on an oscilloscope. The resulting reflection indicates the internal integrity of the test specimen. Flaws are shown as a peak, the size of the peak indicates the size of the fault.

Ultrasonic signals can be recorded if a permanent record is needed. Ultrasonic testing is also used in high-speed automated productions e.g., railway tracks.

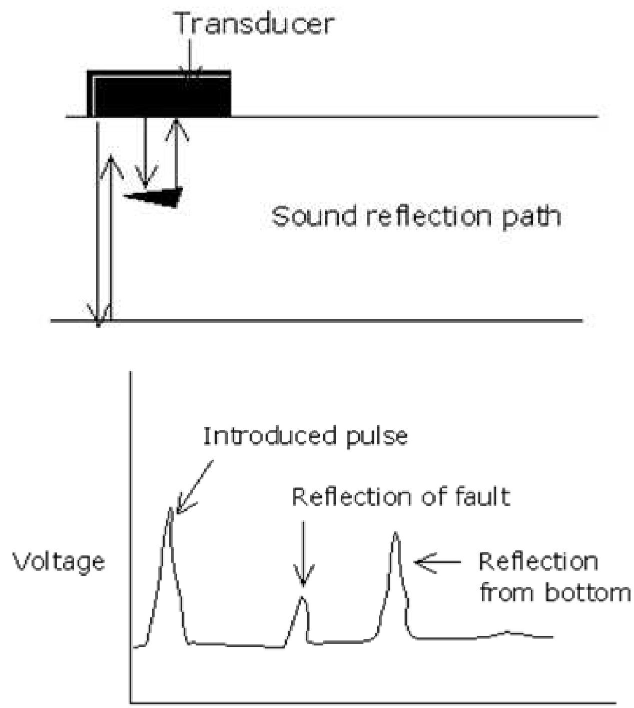

Fig: 13